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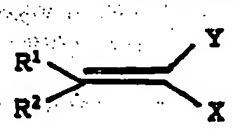
(71) Applicant: THROMBOSIS RESEARCH INSTITUTE
90 Fetter Lane
London EC4A 1EQ (GB)

(72) Inventor: Elgendy, Said Mohamed Anwar
17 Corbet House
Barnsbary Estate, London N1 0HE (GB)
Inventor: Deadman, John Joseph
26B Albion Road
Sutton, Surrey SM2 5TF (GB)
Inventor: Patel, Geeta
99 Bramfield Road
London SW11 6PZ (GB)
Inventor: Green, Donovan St. Claire
137 Southampton Way
Camberwell, London SE5 7EW (GB)
Inventor: Baban, Jehan Anwar
50 Brantwood Road
London SE24 0DJ (GB)
Inventor: Kakkar, Vijay Vir
6 Aspen Copse
Bickley, Kent BR1 2NZ (GB)
Inventor: Claeson, Goran Karl
25 Buffam Road
Pelham, Massachussetts 01002 (US)

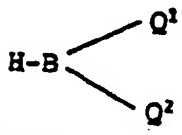
(74) Representative: Linn, Samuel Jonathan et al
MEWBURN ELLIS
York House
23 Kingsway
London WC2B 6HP (GB)

(54) Boronic ester synthesis.

(57) Stable α-substituted boronic esters, e.g. for use in peptide synthesis, are prepared by reacting a substituted alkene of the formula:



with a disubstituted borane of the formula:



wherein:
(i) R^1 and R^2 are each selected from various groups which are preferably not leaving groups;
(ii) X is halogen or other leaving group;
(iii) Y is H or lower alkyl;
(iv) Q^1 and Q^2 are each selected from various groups which are preferably such that the borane is non-hydrolyzable, and particularly Q^1 and Q^2 together may represent a residue of a diol such as catechol or pinanediol.

EP 0 599 633 A1

This invention relates to the synthesis of boronic esters, more particularly the synthesis of α-substituted boronic esters.

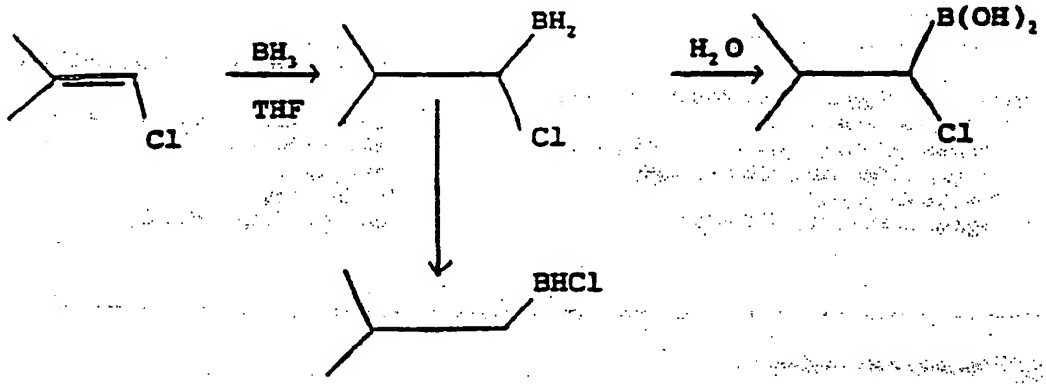
α-substituted boronic esters such as α-halo boronic esters are highly promising and useful intermediates in a variety of organic syntheses. They are especially valuable in the synthesis of α-amino boronic esters, as described in Tetrahedron Lett., 1992, 33, 4209-4212, S. Elgendy, J. Deadman, G. Patel, D. Green, N. Chino, C. Goodwin, M.F. Scully, V.V. Kakkar and G. Claeson. These compounds are also useful in the synthesis of peptides, for example as described in published International Patent Application No. WO 92/07869.

A review of uses of α-halo boronic esters is given in Chem. Rev., 1989, 89, 1535-1551, D.S. Matteson.

Hitherto in the literature only two methods have been reported for the direct synthesis of α-halo boronic esters via hydroboration, as described in J. Am. Chem. Soc., 1968, 90, 2915, H.C. Brown and R.L. Sharp.

Firstly, as disclosed in US Patent No. 3093674 (W. H. Schechter), $(MeO)_2BCHClCH_2Cl$ has been synthesized by the reaction of $(MeO)_2BH$ with E-1,2-dichloroethene. The product obtained from the hydrolysis however was contaminated with boric acid, which is corrosive and difficult to remove and therefore reduces the usefulness of the prepared ester in subsequent applications, particularly in peptide synthesis.

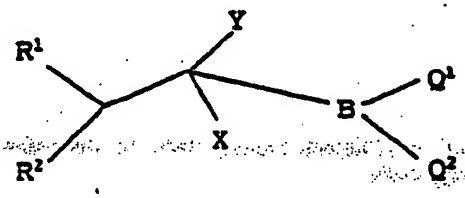
Secondly, as disclosed in J. Am. Chem. Soc., 1968, 90 6259-6260, D.J. Pasto, J. Hickman, T-C Cheng, an alternative method which has been used to prepare α-halo boronic acids is the hydroboration of 1-chloro-2-methyl propene with an equivalent of borane followed by hydrolysis, which yielded (1-chloro-2-methyl propyl) boronic acid. However, if the hydroboration mixture was allowed to stand in THF at room temperature for several hours or if excess BH_3, were added, the intermediate α-substituted borane rearranged to isobutyl chloro borane. These reactions are illustrated by the following reaction scheme:



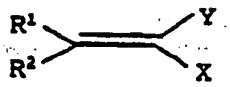
In EP-A-0212708 there are described special catalysts containing rhodium or ruthenium which are useful in the hydroboration (by catecholborane) of various unsaturated hydrocarbon species such as alkenes and alkynes. However, this disclosure is limited to the hydroboration of unsaturated compounds which are unsubstitued.

Surprisingly, we have now found a novel preparative route to stable α-substituted boronic esters, which solves or at least ameliorates the disadvantages of the prior art preparation methods of these compounds.

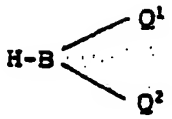
Accordingly, in a first aspect the present Invention provides a process for preparing a compound of the formula



comprising reacting a substituted alkene of the formula



with a disubstituted borane of the formula



wherein:

(i) R^1 and R^2 are the same or different and are each independently selected from any of the following groups:

(a)-$(CH_2)_nG^1$

(b)-$(CH_2)_nAr\ G^1$

(c)-$(CH_2)_nG^2Ar$

- where G^1 is H, halogen, amino, amidino, imidazole, guanidino or isothioureido; G^2 is a linking group derived from an amino, amidino, imidazole, guanidino or isothioureido residue; n in any one or all of (a), (b) and (c) above is an integer of from 0 to 5, preferably from 0 or 1 to 4; Ar is phenyl, thienyl, pyridyl, naphthyl, thionaphthyl, quinolyl, chromenyl, indolyl or wholly or partially (especially in the heterocyclic moiety, if present) saturated groups corresponding to any of these, any of the foregoing groups being optionally substituted with up to 8, preferably up to 5, possibly up to 3, groups selected from C_1-C_3 alkyl and C_1-C_3 alkoxy and optionally being bonded to G through a sulphonyl group;

(d) C_3-C_9 alkyl;

(e) C_5-C_{10} aryl or alkylaryl

- where any of said alkyl, aryl or alkylaryl groups are optionally substituted with up to 3 groups selected from -OH and C_1-C_4 alkoxy;

or R^1 and R^2 are as defined above but are linked together to form a cyclic structure;

(ii) X is halogen, preferably Cl, Br, I or F, or other nucleofuge;

(iii) Y is H or an alkyl, preferably C_1-C_4 alkyl, group; and

(iv) Q^1 and Q^2 are the same or different and are each independently selected from any of the following groups:

- halogen; $-OZ^1$; $-NZ^1Z^2$; where Z^1 and z^2 are the same or different and are each independently selected from C_1-C_{10} alkyl, C_5 or C_6 aryl or C_6-C_{10} alkylaryl;

or Q^1 and Q^2 taken together represent a residue of a diol, eg. catechol, pinacol, pinanediol, or dithiol, eg. ethanedithiol.

In certain embodiments of the above process, the identities of R^1 and R^2 may be such that neither is a leaving group, so that there is site-specific addition of the borane at the 2-position on the alkene. Thus, in such embodiments, when R^1 or R^2 is $-(CH_2)_nG$ and G is halogen or optionally some other leaving group, then n is not 0.

It may be preferred in certain embodiments that the groups Q^1 and Q^2 are such that the disubstituted borane is a non-hydrolysable borane, for example certain of those possibilities mentioned above such as Q^1 and Q^2 together being a catechol or a pinanediol residue.

The above reaction may be readily carried out in the absence of any additional solvent, though it may if desired be carried out in a medium consisting of or comprising an inert solvent, preferably an organic solvent, such as hexane, THF, benzene, toluene, various ethers and other similar solvents known in the art.

Generally the reaction takes place readily at elevated temperatures such as in the range of about 40 to about 120°C, more preferably in the range of from about 60 to about 110°C, even more preferably in the region of about 80°C. The reaction time may be selected as necessary to achieve the desired product yield, and may depend on other reaction parameters such as temperature. By way of example however, reaction times of a few hours up to several, eg. 24 or even 48 hours or more, may be typical. As a general rule, however, the reaction temperature and duration should not be such that there is any or any substantial decomposition of the reactants or product.

Advantageously, the reaction may be carried out whilst irradiating the reacting mixture with ultrasound, in order to induce a faster rate of reaction.

In alternative embodiments of the process of the invention, the above reaction may be readily carried out in accordance with the methods disclosed in and using the special rhodium or ruthenium-based catalysts described in, EP-A-0212708 mentioned above, the disclosure of which document is incorporated herein by reference.

Typically, in such catalysed reactions the substituted alkene defined above is reacted with catecholborane in an organic solvent (such as those mentioned above) preferably at room temperature (eg. from 15 to 25°C, though temperatures between about 0°C and 40°C are possible), in the presence of the catalyst, which is a complex of any of the following formulae:

(i)

$$RhCl(CO)_{\chi}[E(C_6H_5)_3]_{3-\chi}$$

wherein E is arsenic or phosphorus and χ is 0 or 1,

(ii) $[RhCl(alkene)_2]_2$

(iii) $[(C_6H_5)_3P]_3\ Ru(CO)ClH$ or

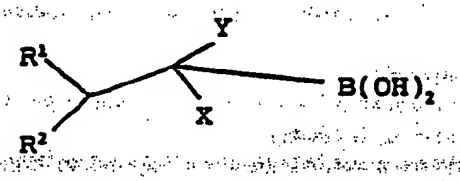
(iv) $[(C_6H_5)_3P]_3\ RuCl_2$.

The α-substituted boronic esters prepared by the above methods are useful for example as intermediates in the preparation of other boron-containing compounds such as α-amino boronic esters, as referred to hereinabove. The esters may also be useful in the synthesis of peptides, including for example certain of those disclosed in WO 92/07869 referred to above, the disclosure of which publication is incorporated herein by reference. In particular, especially useful intermediates derived from the α-substituted boronic esters prepared in accordance with the present invention are α-substituted boronic acids.

Accordingly, in a second aspect the present invention provides a process for preparing an α-substituted boronic acid, comprising:

(i) preparing an α-substituted boronic ester in accordance with the first aspect of the invention; and

(ii) hydrolysing the product of step (i) to form an α-substituted boronic acid of the formula



wherein R^1, R^2, X and Y are as defined above.

The invention will now be illustrated by way of example only by the following Examples.

EXAMPLES

Method A - Hydroboration of 1-halo-1-alkenes (no catalyst)

Experimental procedures

Conventional procedures for the manipulation of boron reagents were followed, as are known in the art. Reactions involving the production of air and water sensitive compounds were carried out under a static pressure of argon or nitrogen directly from the cylinder through a glass line connected via a three-way tap to a vacuum pump. The preparation and purification of reagents for use in these reactions of organoboron compounds were carried out in accordance with well known techniques.

All glassware, syringes, and needles were oven-dried at 140°C for several hours. The glassware was assembled hot and cooled under a stream of dry nitrogen or argon introduced via hypodermic needles inserted through serum capped inlets with outlets protected by inert oil bubblers. Manipulation of liquids was carried out under an inert atmosphere, using syringes and double-ended needle techniques. Syringes were assembled and fitted with needles while hot and then cooled as assembled units. Unless otherwise stated, the apparatus for reactions at below room temperature consisted of a septum capped flask and a coated magnetic follower to enable stirring of the reaction mixture via an external magnetic stirrer. A bleed needle to the argon line was inserted through the cap to allow for any changes in the pressure within the vessel during reaction. Apparatus for reactions at elevated temperatures consisted of a two-necked round-bottomed flask; one neck equipped with a septum capped tap adaptor, the other with a septum capped reflux condenser carrying a nitrogen bleed.

Preparations

Catecholborane (6g, 50 mmol) was added dropwise to the 1-halo-1-alkene (50 mmol). The reaction mixture was heated under reflux under argon and monitored by the disappearance of the olefinic protons in the proton NMR. The α-haloboronic ester was obtained by distillation at 90-120°C/0.05 mmHg in 59-83% yields.

(+)Pinanediol 1-halo alkaneboronic esters were prepared by adding one equivalent of the catecholboronic ester to a solution of (+)-pinanediol in THF.

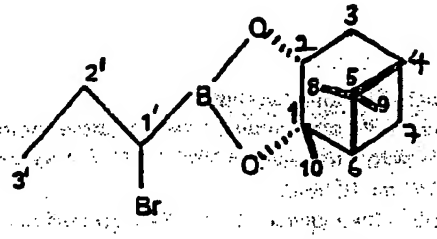
The reaction mixture was left stirring at room temperature for two hours. The solvent was removed under vacuum and the residue was purified on a column of silica gel (230-400 mesh). Elution with hexane gives the desired products as colourless oils in 85-90% yield.

Example 1

(+) Pinanediol-1-bromo propane boronate

Catecholborane (50mmol) was added dropwise to 1-bromo-1-propene at 80°C. After refluxing the reaction mixture under nitrogen for 24h, the resulting crude product was treated with a solution of (+) pinanediol (50mmol, 8.5g) in THF (20ml) and the reaction mixture was stirred under nitrogen at room temperature for a further 2 hours.

Solvent was removed under vacuum, the resulting crude product was placed on a column of silica gel (230-400 mesh), eluted with hexane to give the desired product as a colourless oil in 76% yield.



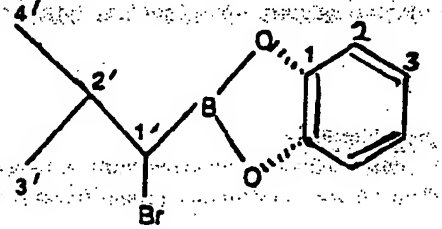
m/z 302 (M+H); δ_B 31.13; δ_H 4.34-4.39 (1H, m, H-2), 3.27-3.35(1H, m, H-1'), 2.31-2.45(1H, m, H-3), 2.16-2.3(1H, m, H-7) 2.09(1H, t, J=5Hz, H-6), 1.91-2.09(2H, H, H-2') 1.81-1.91(1H, m, H-4), 1.69-1.8(1H, m, H-3), 1.41(3H, s, H-10), 1.29(3H, s, H-9), 1.1(3H, t, J=7Hz, H-3'), 0.8-1.01(1H, m, H-7), 0.85-(3H, s, H-8); δ_C, 86.38(C-1), 78.3(C-2), 51.2(C-6), 39.48(C-4), 38.22(C-5), 35.3(C-3), 28.37(C-10), 27.6(C-2'), 26.9(C-9), 26.2(C-7), 23.94(C-8), 13.41(C-3').

Example 2

(+) Pinanediol-1-bromo 2-methyl propane boronate

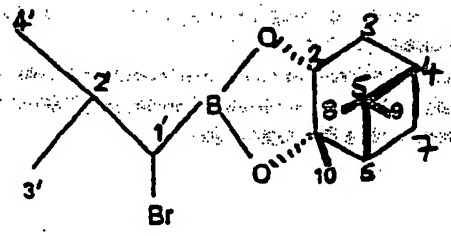
Catechol-1-bromo 2-methyl propane boronate was prepared by refluxing the catecholborane with one equivalent of 1-bromo-2-methyl propene at 80°C for 4 hours. The catecholboronic ester product was obtained by distillation of the reaction mixture at 120°C/1mmHg in 82% yield.

The title compound was prepared by adding one equivalent of the catecholboronic ester to a solution of (+) pinanediol in THF. The reaction mixture was left stirring at room temperature for 2 hours. The solvent was removed and the residue was purified on a column of silica gel, eluted with hexane to give the title compound as a colourless oil in 80% overall yield.



Catechol 1-bromo-2-methylpropylboronate

m/z 256 (M+H); δ_B 32.79; δ_H 7.02-7.28 (4H, m, Ph), 3.65(1H, d, J=7.2Hz, H-1'), 2.09-2.35(1H, m, H-2'), 1.11-1.19(6H, q, H-3' & H-4'); δ_C 147.89(C-1), 123.16(C-2), 112.85(C-3), 31.7(C-2'), 21.38(C-3' & C-4').



(+) Pinanediol 1-bromo-2-methylpropylboronate

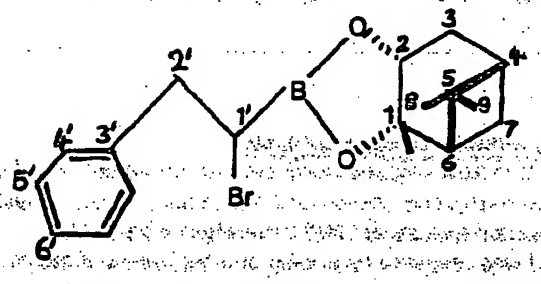
m/z 316 (M+H); δ_B 31.02; δ_H 4.34-4.39 (1H, m, H-2), 3.41(1H, dd, J=8Hz & 1.3Hz, H-1'), 2.23-2.24(1H, m, H-2'), 2.17-2.3(1H, m, H-3), 2.06-2.15(1H, m, H-7), 2.05(1H, t, J=5Hz, H-6), 1.88-1.99(1H, m, H-4), 1.55-1.8(1H, m, H-3), 1.4(3H, s, H-10), 1.2(3H, s, H-9), 1.03-1.11 (6H, m, H-3' & H-4'), 0.9-1.1(1H, m, H-7), 0.85(3H, s, H-8); δ_C 86.38(C-1), 78.3(C-2), 51.27(C-6), 39.57(C-4), 38.3(C-5), 35.44(C-3), 31.62(C-2'), 28.44(C-10), 27.01(C-9), 26.2(C-7), 24.02(C-8), 21.52(C-4'), 21.26(C-3').

Example 3

(+) Pinanediol-1-bromo 2-phenyl ethane boronate

Catechol-1-bromo-2-phenyl ethane boronate was prepared by irradiating the catecholborane and one equivalent of α-bromostyrene with ultrasound at 50°C-60°C for two hours, then, the reaction mixture was left stirring under nitrogen at 60°C for 18 hours.

A solution of (+)pinanediol (one equivalent) in THF was added at room temperature and the reaction was stirred for further two hours. The solvent was removed and the unreacted starting material was removed by distillation at 40°C/0.05 mmHg. The residue was placed on a column of silica gel and eluted with hexane to give the desired product as a colourless oil in 59% yield.

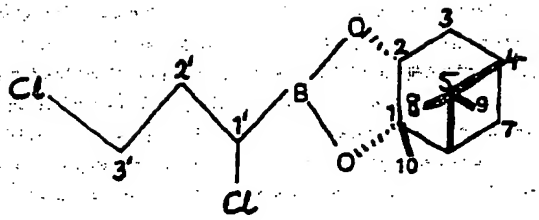


m/z 302 ($M+NH_4$); δ_B 31.80; δ_H 7-02-7-42 (5H, m, Ph), 4.19-4.31(1H, m, H-2), 3.47-3.56(1H, m, H-1'), 3.1-3.32(2H, m, H-2'), 2.2-2.35(1H, m, H-3), 2.05-2.2(1H, m, H-7), 2.12(1H, t, J=5Hz, H-6), 1.71-1.95(1H, m, H-4), 1.7-1.75(1H, m, H-3), 1.32(3H, s, H-10), 1.24(3H, s, H-9), 0.95-1.04(1H, m, H-7), 0.78(3H, s, H-8); δ_C 139.1(C-3'), 129.17(C-5'), 128.24(C-4'), 126.08(C-6'), 86.45(C-1), 78.32(C-2), 51.23(C-6), 40.67(C-2'), 39.23(C-4), 38.21(C-5), 35.16(C-3), 28.27(C-10), 27.09(C-9), 26.37(C-7), 23.96(C-8).

Example 4

(+) Pinanediol 1,3-dichloro propylboronate

The named product was prepared by analogous methods as described in Examples 1 to 3, but using 1,3-dichloropropene as the starting alkene and continuing the refluxing for 24 hours, to give the desired product in 79% yield.



m/z 308 (M+H); δ_B 31.44; δ_H 4.2-4.39 (1H, m, H-2), 3.71-3.77(2H, m, H-3'), 3.54(1H, t, J=6Hz, H-1'), 2.35-2.41(1H, m, H-3), 2.25-2.32(2H, m, H-2'), 2.2-2.25(1H, m, H-7), 2.08(1H, t, J=5Hz, H-6), 1.93-1.99(1H, m, H-4), 1.91-1.93(1H, m, H-3), 1.42(3H, s, H-10), 1.3(3H, s, H-9), 1.01-1.22(1H, m, H-7), 0.84(3H, s, H-8); δ_C 87.05(C-1), 78.74(C-2), 51.31(C-6), 42.12(C-3'), 39.37(C-4), 38.27(C-5), 36.55(C-2'), 35.23(C-3), 28.40(C-10), 27.04(C-9), 26.5(C-7), 23.94(C-8).

Example 5

(+) Pinanediol 1-chloro-2-methyl propylboronate

Example 2 was repeated but using 1-chloro-2-methyl propene as the starting alkene and continuing the refluxing for 18 hours.

The final named product was obtained in 66% yield.

Example 6

(+) Pinanediol 1,3-dibromo propylboronate

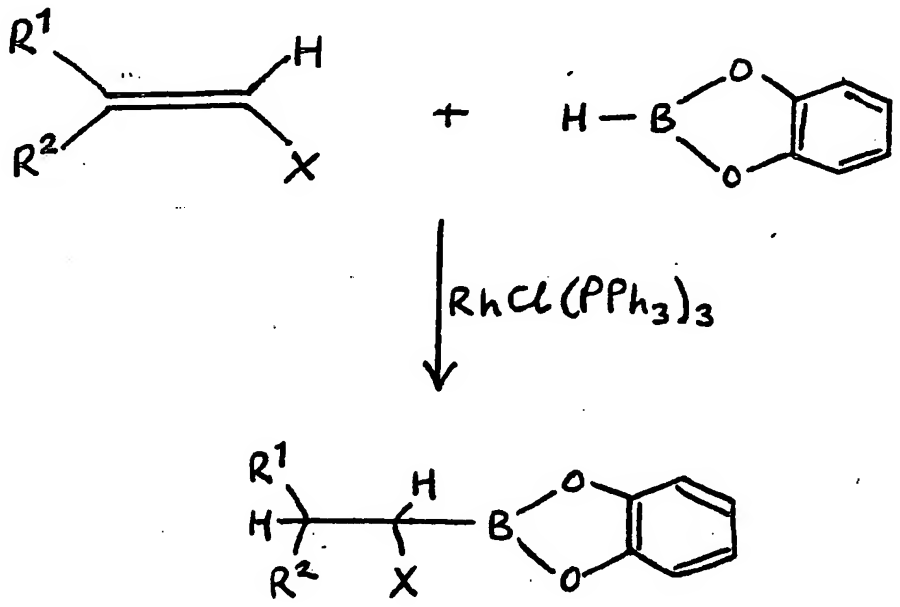
Example 4 was repeated but using 1,3-dibromo propene as the starting alkene and continuing the reflux for only 8 hours.

The final named product was obtained in 76% yield.

Method B - Catalysed hydroboration of 1-halo-1-alkenes by catecholborane

Preparations

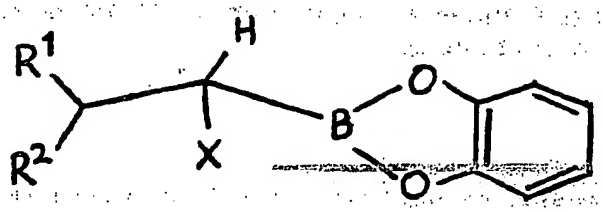
Using similar experimental procedures as in the preparations of Method A, the reaction method was carried out according to the following equation:



In the presence of Wilkinson's catalyst (0.05-0.5% mol equiv. as indicated in Table 1 below for each Example), catecholborane (45mmol, 5.4g) was added dropwise to the appropriate 1-halo-1-alkene (3 mmol) in benzene (5ml), using conventional techniques for handling air sensitive material, and the mixture refluxed for a period as indicated in Table 1 below for each Example. The reaction mixture was left stirring at room temperature, and monitored by the disappearance of the olefinic protons from the ^1H nmr spectrum, until the reaction was complete. The desired product was isolated by distillation (using a Kugelrohr distillation apparatus under vacuum) in quantitative yields as indicated in Table 1 below for each Example.

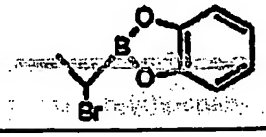
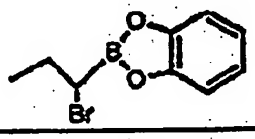
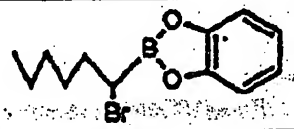
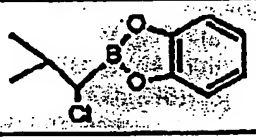
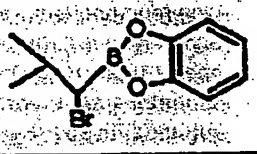
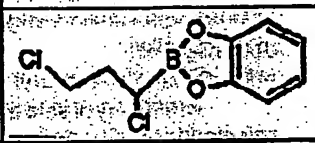
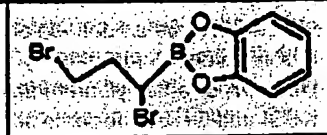
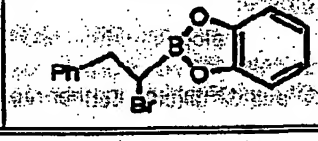
Examples 7-14

Compounds of the formula:



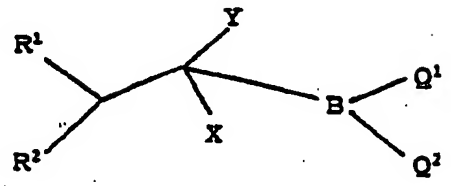
wherein R^1, R^2 and X have the identities shown in Table 1 below were prepared by the above preparative method using analogous starting materials as for Examples 1 to 6.

TABLE 1

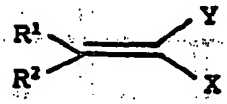
Example	R^1	R^2	X	Catalyst %	Reaction Time (h)	Isolated Product	% yield
7	H	H	Br	0.1	38		73
8	Me	H	Br	0.1	8		82
9	$CH_3(CH_2)_3$	H	Br	0.5	48		54
10	Me	Me	Cl	0.2	24		70
11	Me	Me	Br	0.05	28		98
12	$ClCH_2$	H	Cl	0.2	30		71
13	$BrCH_2$	H	Br	0.1	5		79
14	Ph	H	Br	0.1	30		87

Claims

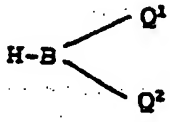
1. A process for preparing a compound of the formula



comprising reacting a substituted alkene of the formula



with a disubstituted borane of the formula



wherein:

(i) R^1 and R^2 are the same or different and are each independently selected from any of the following groups:

(a)-$(CH_2)_nG^1$

(b)-$(CH_2)_nAr\ G^1$

(c)-$(CH_2)_nG^2Ar$

- where G^1 is H, halogen, amino, amidino, imidazole, guanidino or isothioureido; G^2 is a linking group derived from an amino, amidino, imidazole, guanidino or isothioureido residue; n in any one or all of (a), (b) or (c) above is an integer of from 0 to 5, preferably from 0 or 1 to 4; and Ar is phenyl, thienyl, pyridyl, naphthyl, thionaphthyl, quinolyl, chromenyl, indolyl or wholly or partially saturated groups corresponding to any of these, any of the foregoing groups being optionally substituted with up to 8 groups selected from C_1-C_3 alkyl and C_1-C_3 alkoxy and optionally being bonded to G through a sulphonyl group;

(d) C_3-C_9 alkyl;

(e) C_5-C_{10} aryl or alkylaryl

- where any of said alkyl, aryl or alkylaryl groups are optionally substituted with up to 3 groups selected from -OH and C_1-C_4 alkoxy;

or R^1 and R^2 are as defined above but are linked together to form a cyclic structure;

(ii) X is halogen, preferably Cl, Br, I or F, or other nucleofuge;

(iii) Y is H or an alkyl, preferably C_1-C_4 alkyl, group; and

(iv) Q^1 and Q^2 are the same or different and are each independently selected from any of the following groups:

- halogen; $-OZ^1$; $-NZ^1Z^2$; where Z^1 and Z^2 are the same or different and are each independently selected from C_1-C_{10} alkyl, C_5 or C_6 aryl or C_6-C_{10} alkylaryl;

or Q^1 and Q^2 taken together represent a residue of a diol or dithiol.

2. A process according to claim 1, wherein in the formula of the alkene R^1 or R^2 is $-(CH_2)_nG$ and G is halogen or optionally some other leaving group, but wherein n is not 0.

3. A process according to claim 1 or claim 2, wherein the said disubstituted borane is non-hydrolyzable.

4. A process according to claim 3, wherein in the definition of Q^1 and Q^2 the said diol is selected from cat-

echol, pinacol or pinanediol.

5. A process according to any one of claims 1 to 4, wherein the reaction is carried out in an inert solvent.

6. A process according to any one of claims 1 to 4, wherein the reaction is carried out in the absence of an inert solvent.

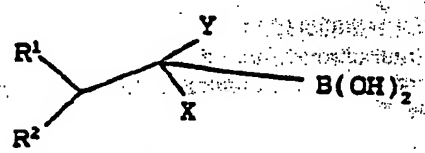
7. A process according to any one of claims 1 to 6, wherein the reaction is carried out at a temperature at which there is substantially no decomposition of the reactants and the product.

8. A process according to claim 7, wherein the reaction temperature is in the range 40 to 120°C.

9. A process according to claim 8, wherein the reaction temperature is in the range 60 to 110°C.

10. A process according to any preceding claim, wherein the reaction is carried out under irradiation with ultrasound.

11. A process for preparing an α-substituted boronic acid, comprising:
preparing an α-substituted boronic ester in accordance with the process of any preceding claim; and
hydrolysing the product of step (i) to form an α-substituted boronic acid of the formula



wherein R^1, R^2, X and Y are as defined above.

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 93 30 9372

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
D,X	EP-A-0 212 708 (METALLGESELLSCHAFT AG) * the whole document *	1-11	C07F5/02
D,Y	US-A-3 093 674 (SCHECHTER, W.H.) * the whole document *	1-11	
Y	JOURNAL OF THE AMERICAN CHEMICAL SOCIETY vol. 101, no. 1 , 1979 pages 248 - 249 MIDLAND, M.M. ET AL. 'STEREOCHEMISTRY AT THE MIGRATION TERMINUS IN THE BASE-INDUCED REARRANGEMENT OF .ALPHA.-HALOORGANOBORANES' * page 248: hydroboration of (Z)-1-halo-2-methyl-1-butenes with diethylborane *	1-11	
A	THE JOURNAL OF ORGANIC CHEMISTRY vol. 56 , 1991 pages 3286 - 3294 RANGAISHENVI, M.V. ET AL. 'CHIRAL SYNTHESIS VIA ORGANOBORANES. 30. FACILE SYNTHESIS, BY THE MATTESON ASYMMETRIC HOMOLOGATION PROCEDURE, OF .ALPHA.-METHYL BORONIC ACIDS NOT AVAILABLE FROM ASYMMETRIC HYDROBORATION AND THEIR CONVERSION INTO THE CORRESPONDING ALDEHYDES, KETONES, CARBOXYLIC ACIDS, AND AMINES ETC.' * the whole document *	1-11	

TECHNICAL FIELDS SEARCHED (Int.Cl.5)
C07F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	4 February 1994	Rinkel, L

CATEGORY OF CITED DOCUMENTS

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